Introduction to Engines: A General View and Application to Model Rocket Engines

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Rocket Introductory Information

- Blend of practical model information and Background information
- Rocket basics
  - Engine
  - Aerodynamics
  - Vehicle Statics/Dynamics
- “How to use the Newton’s Laws
  - Newton’s 3 Laws
- Mission? -work on the process.

Law of Inertia

An object at rest, or in uniform straight line motion, will remain at rest, or in uniform straight line motion, unless acted upon by a net external force.

This is easier to write mathematically.

$$\text{if } \sum_{i=1}^{\infty} \bar{F}_i = 0, \text{ then } \bar{v} = \text{constant}$$

which translates to: if we add up all of the forces acting on a body from 1 to infinity and get zero as the resultant, then the body is moving with constant velocity.

The converse of this is true as well.

Newton's 2nd Law

- **A net force acting on a body produces on that body, an acceleration that is directly related to the force impressed upon the body and inversely related to the mass of the body.**

- Newton also explains what happens when the forces do **not** add up to be zero

An easier way to state it is:

$$\text{if } \sum_{i=1}^{\infty} \bar{F}_i = \bar{F}_{net}, \text{ then } \bar{F}_{net} = m\bar{a}$$

Notice that the equation is a vector equation. The acceleration is in the same direction as the net force.

The units of force are directly derived from this formula

$$N = kg\ {}^{m}/_{s}{}^{2}$$

3rd Law, Weight, and Normal Force

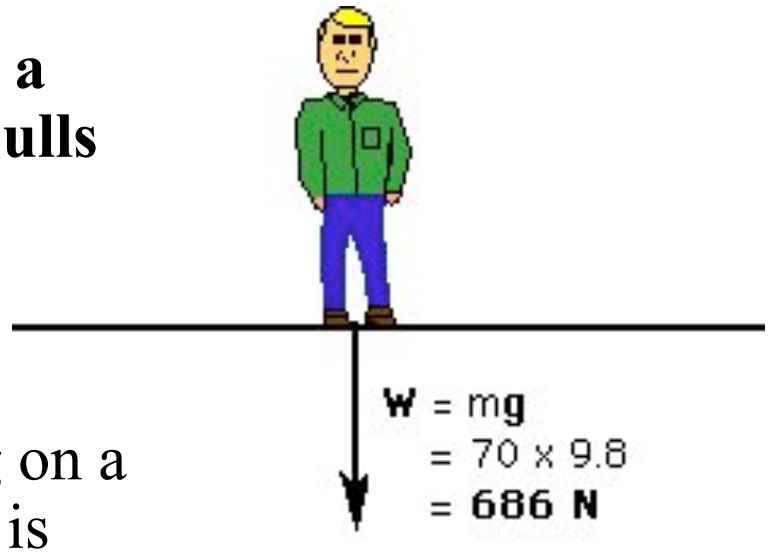
- For every action there is an equal but opposite reaction

or mathematically stated: $F_{ab} = -F_{ba}$

It is an observation of Newton, that forces naturally occur in pairs

Example: **Weight - the force with which a gravitational body (such as the earth) pulls on a body**

Mathematically: **W** = **mg**



When a person (mass = 70 kg) is standing on a floor the force that they exert on the floor is their weight

Newton's Law

$$F = \frac{d}{dt}(mV)$$

$$F = ma$$

$$F = \frac{dm}{dt}(V) \qquad F = m\frac{dV}{dt}$$

Newton's Law

$$F = \frac{dm}{dt}(V)$$

Generate a large Velocity

Move a lot of Mass

Boeing 777

- State of the ART
- 1990 Design

777 INFO

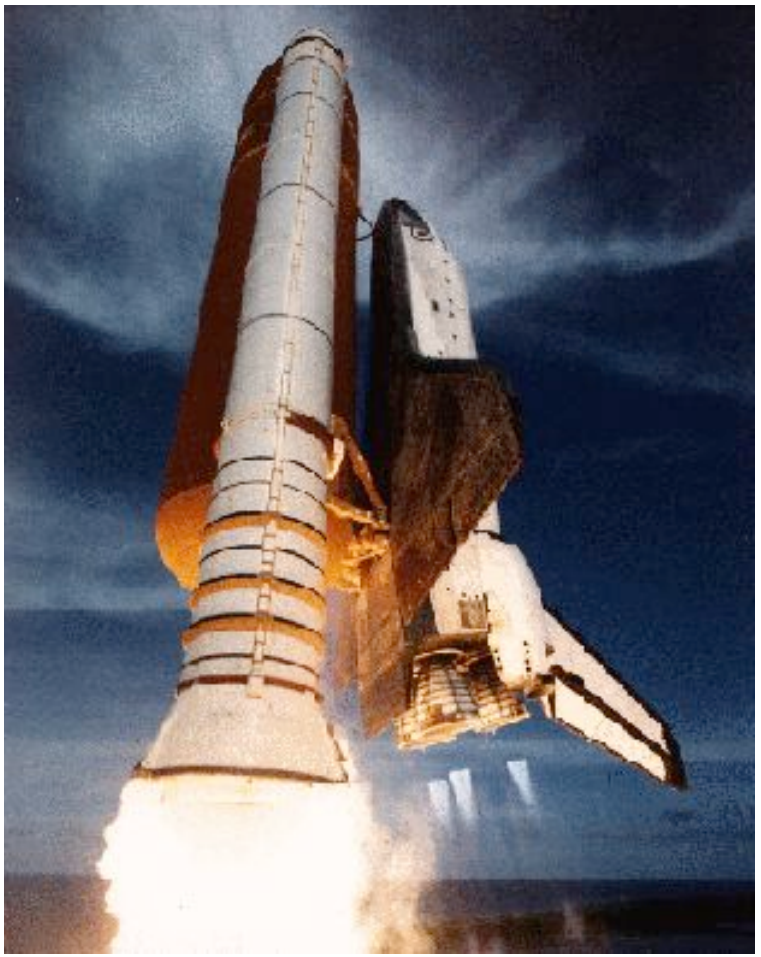
- 777-200
- Take off Weight 506,000 lbs
- Range 4350 nmi
- Fuel Capacity ~ 37000 gals
- Engines GE90, PW4084, RRTrent 890
- Thrust Class, 105,000 lbf (Peak GE90), ~90,000 lbf, 84,600lbf(PW 4084), demonstrate 90,000 lbf, 90,000 lbf (Trent 800)

What does it mean?

- Weight of Fuel = 37000 gal*7 lbm/gal =259,000lb (51%)
- Passinger Capacity ~ 400 * 250 lb/per person =100,000 lb (19%) plus baggage etc..
- Structual Weight ~ 147Klbs (~30%) and less

Space Shuttle

- 4.5 million lb (~8 of 777)
- Payload capacity 65,000lbs
- 1.4 % payload fraction
- SSME ~ 400,000 lb
- 1.6 million lb propellant (35.5 %)
- ~ 1 million lb Solids (22 %)
- ~ 5.2 million lb thrust
- ~ 9 * 777 thrust



Saturn V -Moon Rocket

- 3.08 million Kg (6.776 million lb)
- 118,000 kg LEO (3.8%) and 47,000 kg Moon (1.5%)
- 3.4 million kg 5 F1 engines (7.48 million lb)

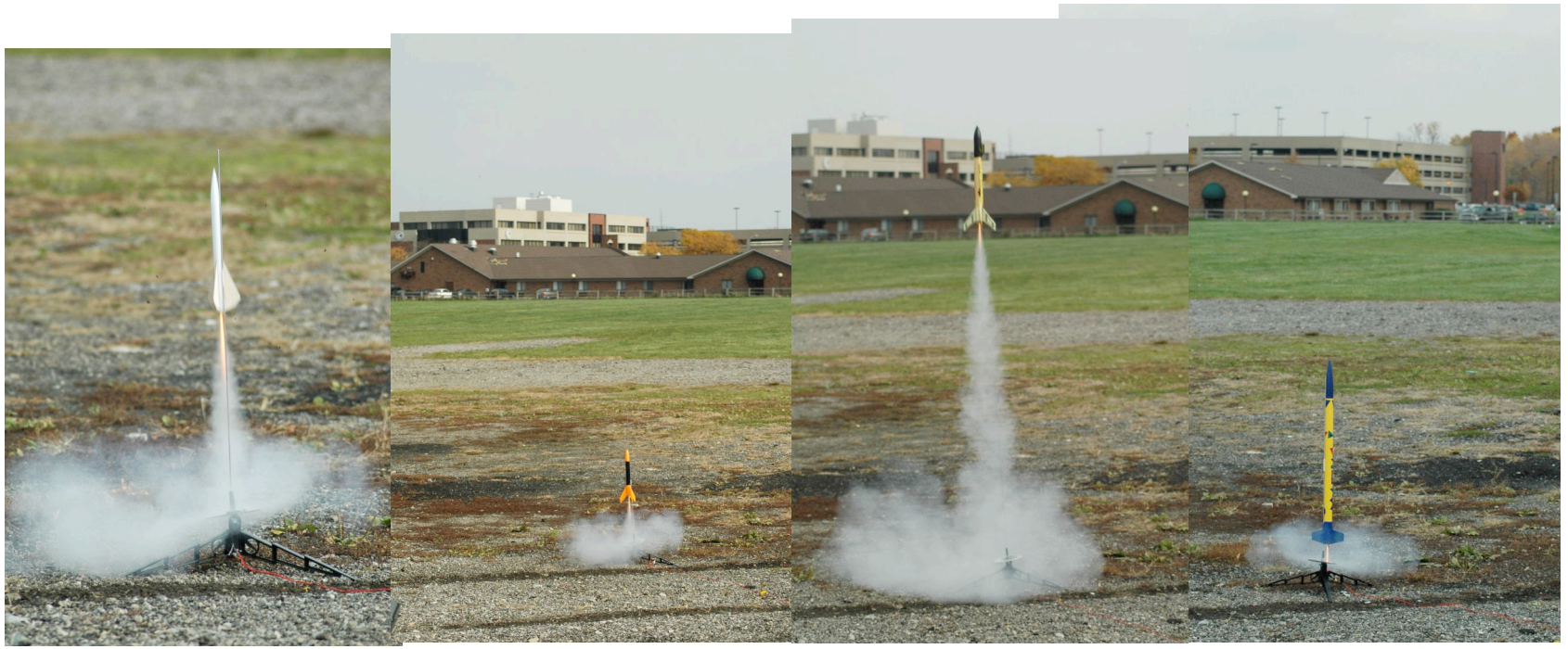
Reference Values

- 2001 VW Jetta Sedan ~ 4000 #
- 126 VWs are equal to one 777
- 1102 are equal to one space shuttle fully stacked

- Rule of thumb 2.5 lb thrust/HP (turbojets)
- Wright Aircraft 12 HP (30 lb)
- 2001 VW Jetta Sedan ~ 105HP (262 lb)

Prep

3-2-1 Launch



Need work on the details

How to use the Newton's Law

Thrust Force - Weight - Drag = Mass * Acceleration

Drag = $1/2*rho*V^2C_DA$
Mass = Mass of the Rocket (note this mass changes)
Weight = Mass * Gravitational Acceleration

Simple use of the Newton's Law

$Impulse_{net} = \Delta$ (Mass * Velocity)

Impulse = Mass*Velocity- 0

Thus => Velocity = Impulse/Mass

=> Impulse can be measured !

=> Know Velocity

=> Altitude = Velocity * Time

One problem?

Published Motor Data

A	1.26-2.5	N-s
B	2.51-5	N-s
C	5-10.	N-s
E	20-40	N-s

A 6 -4

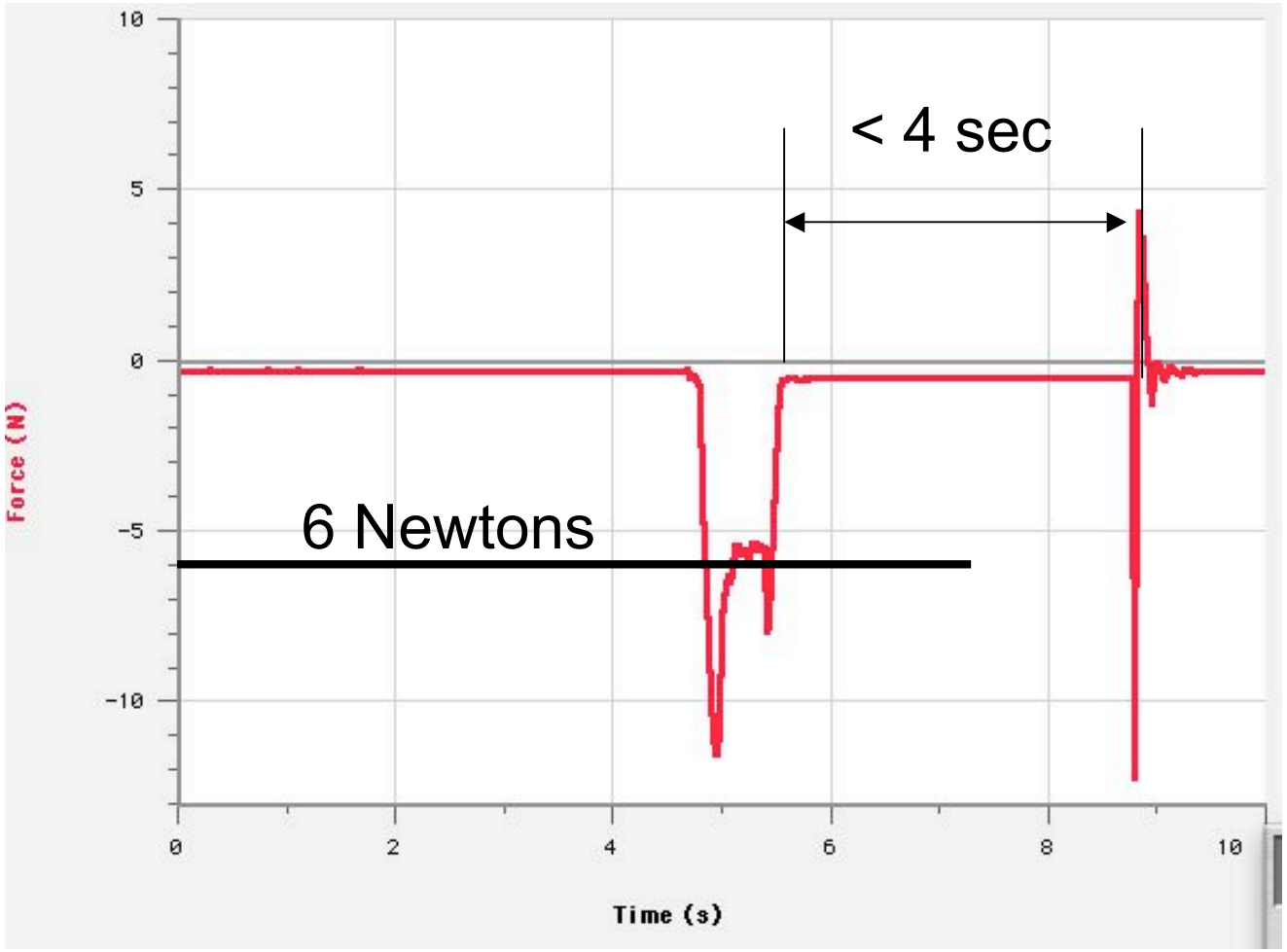
Class

Thrust (Newtons)

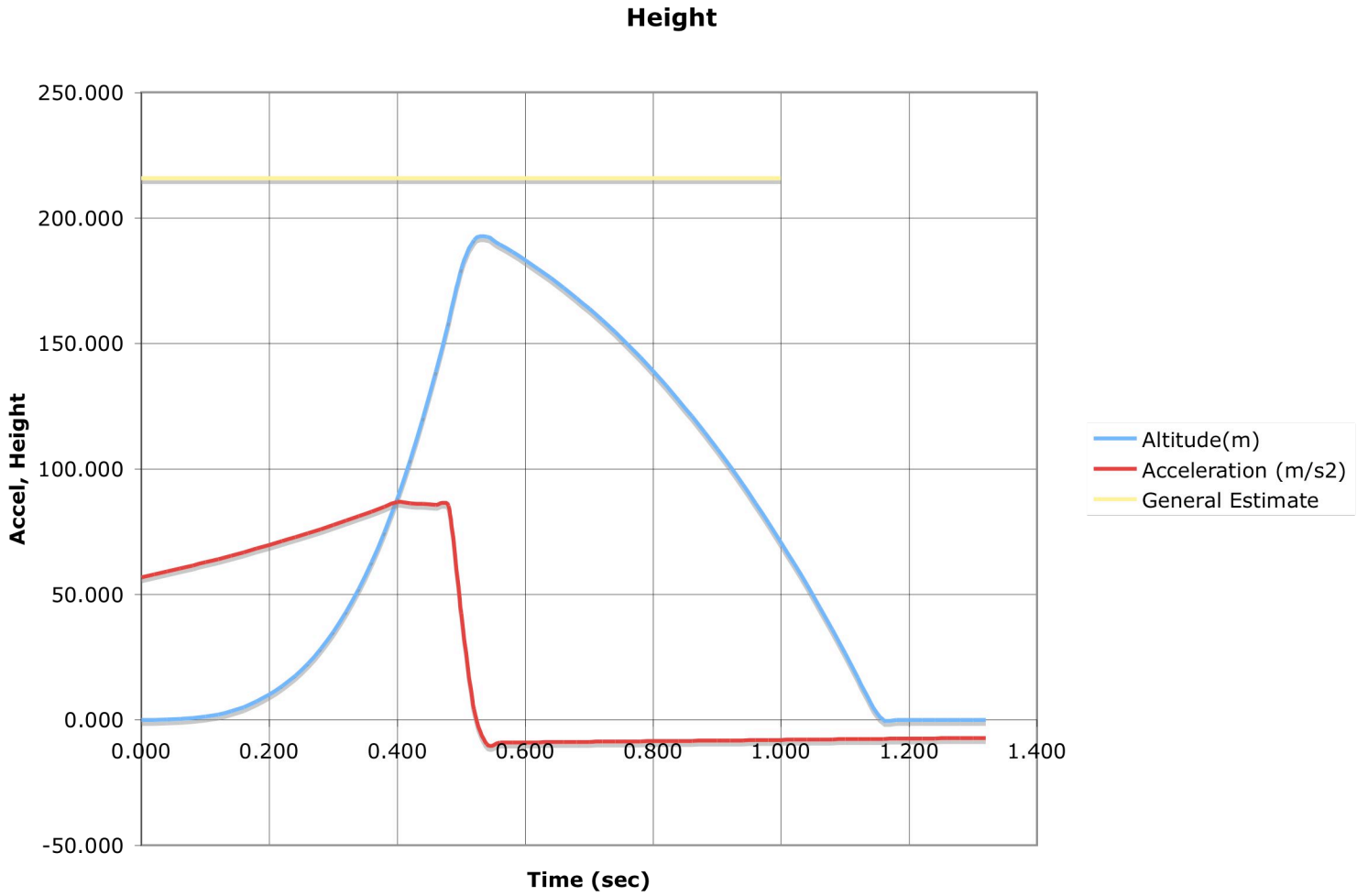
Delay (sec)

Measured Motor Data

B 6 -4



Using the measured Data and Newton's Law



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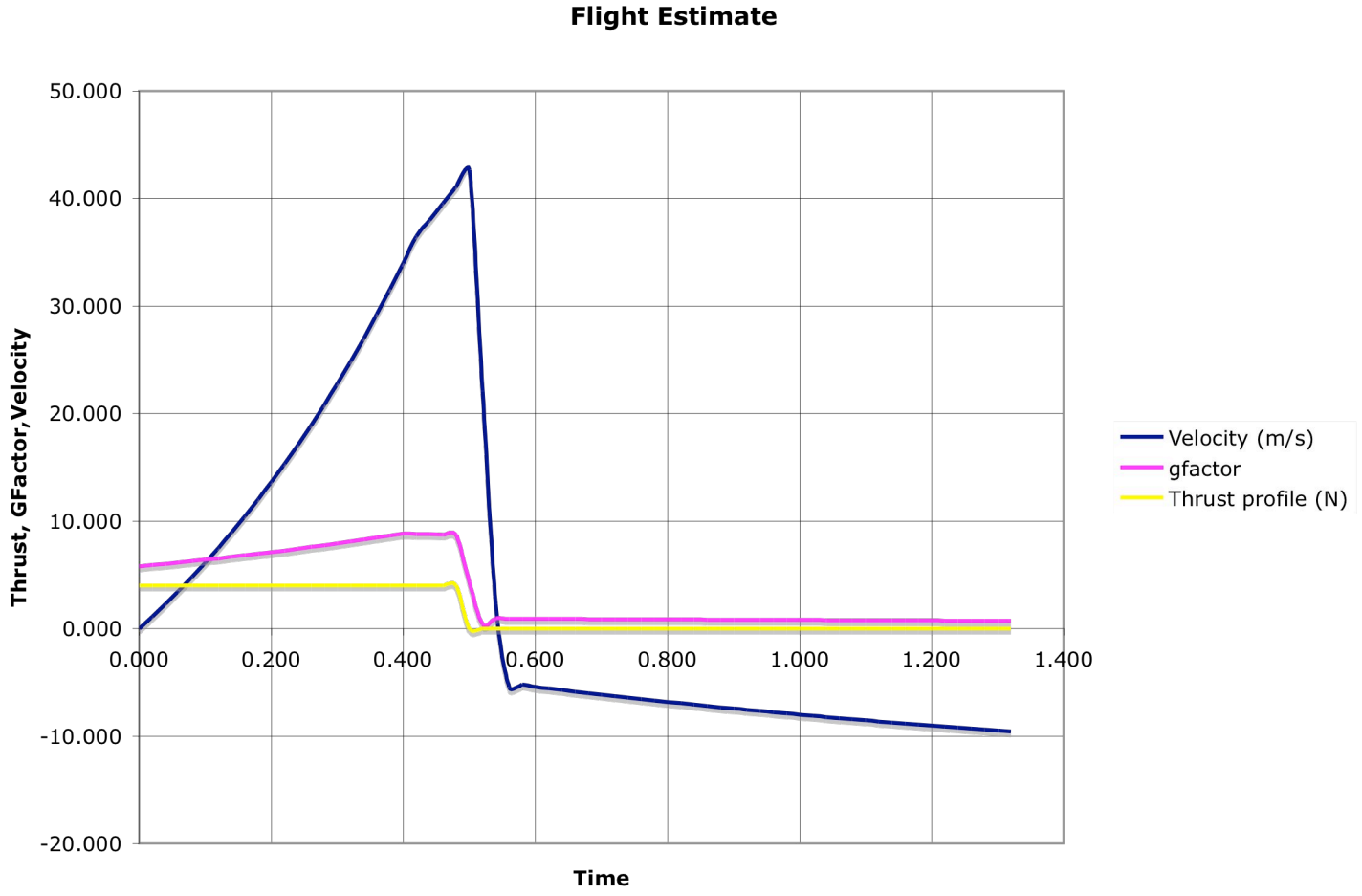
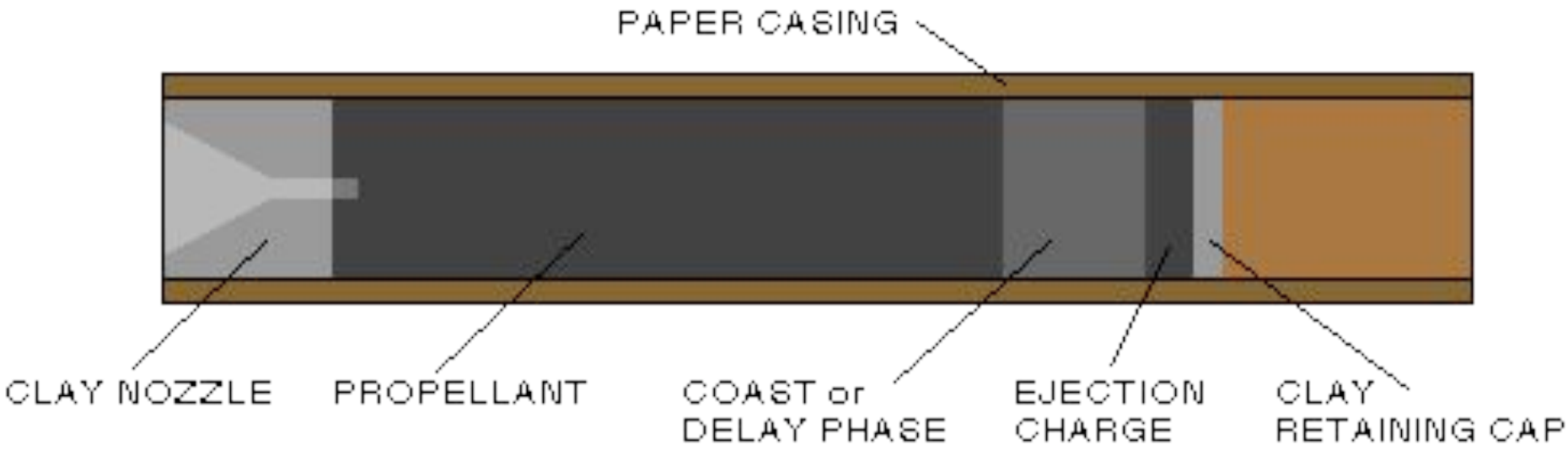


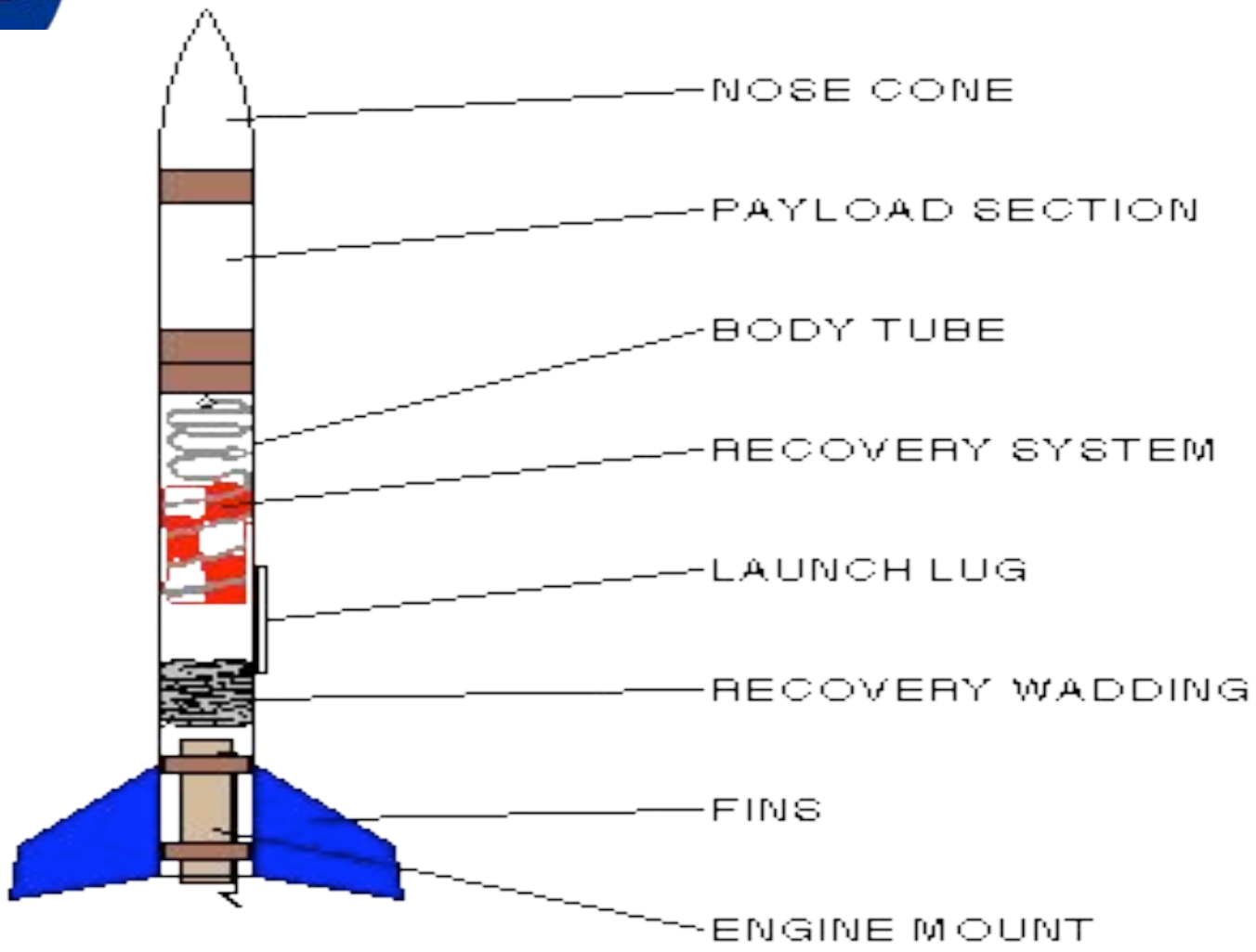
Model Rockets



Chemistry/Combustion

- $21NH_4ClO_4 + 10(C_4H_6) \rightarrow 21HCl + 34.5\ H_2 + 27\ H_2O + 23\ CO + 17\ CO_2$
- Ammonium perchlorate
- Note: Far more interesting than
- $H_2 + 1/2\ O_2 \rightarrow H2O$

Model Rockets



Direction?

- Mission
- Team Work
- We will do the back ground work (Three dimensions, Aerodynamics, Vehicle Dynamics, Structures)
- Develop tools
- Build/Test models
- **Design Review prior to launch.**

Reference Information

- Stine, Handbook of Model Rockets.
- National Association of Rocketry, http://www.nar.org/

Model Rockets

Setup

Clear site Launch

Recovery

Model Rockets

Vehicle

Launch Pad

Launch Controller-
Safety switch